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TECHNICAL MEMORANDUM

AUTHOR(S): D. Yee

TITLE: DCHT - Double Containment Boiler Hydrogen Transport Computer Program for SNAP-8

ABSTRACT

DCHT is a computer program written in FORTRAN IV for the IBM 360 and IBM 1130 that calculates the movement and buildup of hydrogen in the SNAP-8 system. The method used by DCHT is to numerically integrate the finite difference equations describing the system's transient behavior. DCHT is applicable for the SNAP-8 system with a double containment boiler installed.

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Key Words: SNAP-8 Hydrogen Transport, Double Containment Boiler, Transient Behavior, Computer Program, FORTRAN IV

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APPROVED:

DEPARTMENT HEAD R. J. Hefner

The information in this document is subject to revision as analysis progresses and additional data are acquired.

AEROJET-GENERAL CORPORATION

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NUCLEAR DIVISION

AEROJET-GENERAL CORPORATION

San Ramon, California

I. INTRODUCTION AND SUMMARY

This memorandum, written as a supplement to reference 1, describes a FORTRAN computer code - DCHT (Double Containment boiler Hydrogen Transport) that calculates the movement and buildup of hydrogen around the SNAP-8 system with a double containment boiler installed. The main difference between the computer code described in reference 1 and DCHT is the equations describing the behavior of hydrogen in the boiler. Only the differences between the two codes will be described in this memorandum.

From early attempts at writing this codes, it was found that if the stagnant NaK and tantalum tube in the boiler were treated as separate nodes, the allowable numerical integration interval was on the order of hundreths of an hour. Since such a small integration interval would result in a large running time for the code and is caused by the large transfer coefficient for hydrogen between the tantalum tube and stagnant NaK, it was decided to assume that these materials were in equilibrium. (A large transfer coefficient implies equilibrium between the two materials).

Given in Figure 1 is a flow diagram for DCHT. A listing of the main program DCHT is given in Appendix A.

78.40-67-1112

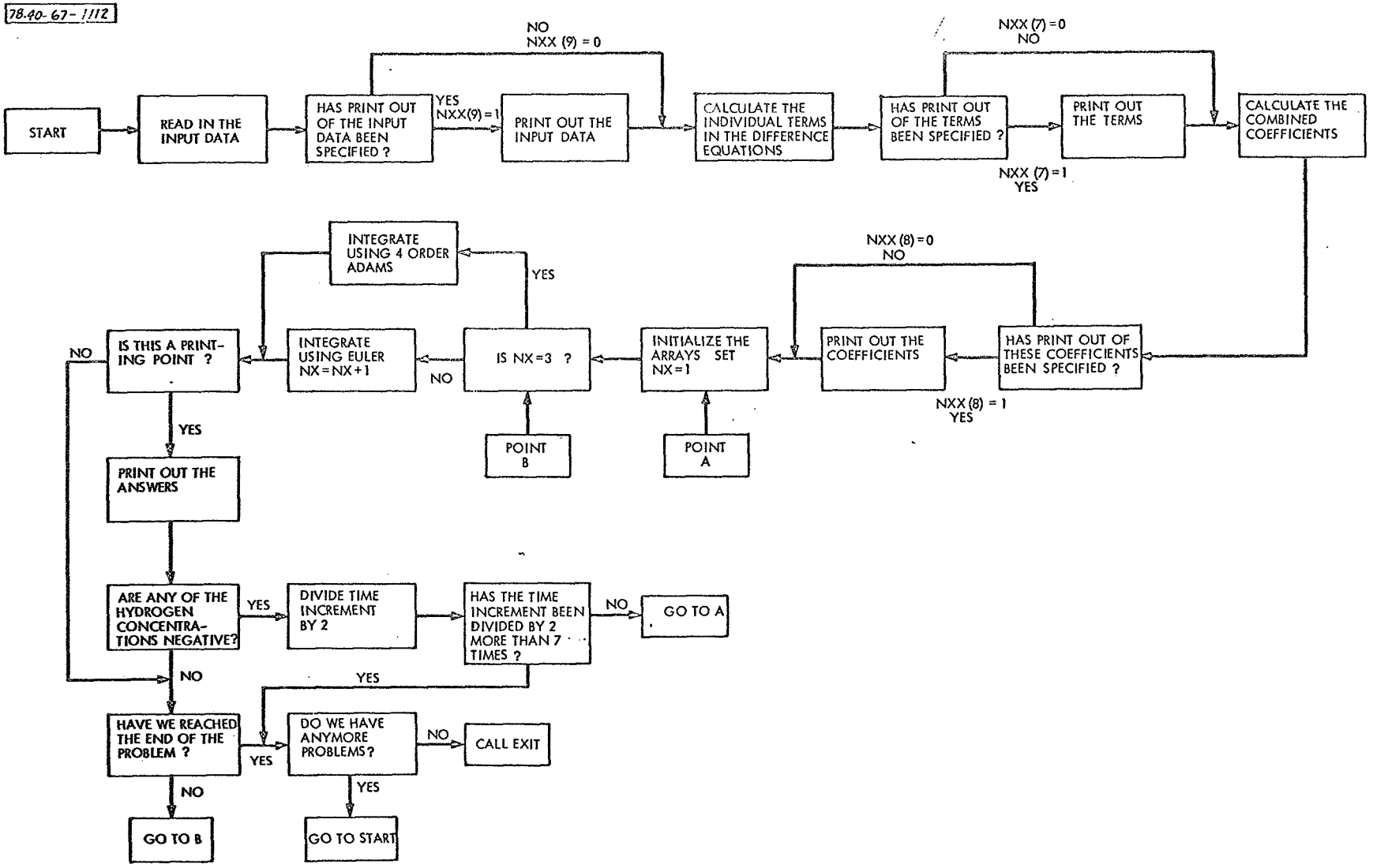

FIGURE 1. FLOW DIAGRAM FOR DCHT

II. NOMENCLATURE

The nomenclature used in this writeup and in the code are essentially identical to that described in reference 1. Several additional variables are used and they are defined as follows:

A. MEMORANDUM SYMBOLS

Symbol	Definition
CS	Stagnant NaK hydrogen concentration, μg/g
FS	Multiplier to convert hydrogen concentration in the stagnant NaK to hydrogen partial pressure, micron-g/μg
I_S	Stagnant NaK inventory in the node, g
I_{ST}	Total NaK inventory in the stagnant NaK system, g
KS	Boiler node permeability conductance stagnant NaK to tantalum tube, μg/hr-micron
NL	Number of tantalum tube nodes that are not in equilibrium with the stagnant NaK. These nodes are assumed to be the first NL nodes starting from the mercury boiler inlet, non-dimensional
TH	The total amount of hydrogen contained in the stagnant NaK system and the boiler tantalum tube nodes that are considered to be in equilibrium with the stagnant NaK, μg

B. PROGRAM SYMBOLS

The following section defines the FORTRAN symbols appearing in the COMMON statement of the main program that are not covered in reference 1.

FORTRAN Symbol	Definition
CN	The hydrogen concentration of the NaK in the primary NaK system. The first value is the present value. The second is the previously calculated value, μg/g
CNC	Same as CN for the NaK in the heat rejection system, μg/g
CNCS	+ (CS) (CN) (1a)
CP	The hydrogen concentration in the boiler plug node. There are two values for each node. See CN for the definition of these 2 values, μg/g
CS	Same as CN for the NaK in the stagnant NaK system, μg/g
CWCS	+ (CS) (CW) (2a)
CW	Same as CP for the boiler tantalum tube, μg/g
DTH	The time rate of change (derivative) of the total hydrogen contained in the stagnant NaK system and the boiler tantalum tube nodes that are considered to be in equilibrium with the stagnant NaK. There are four values stored in single subscript notation. The fourth value is the derivative at the present time. The preceding values are at preceding integration times, μg/hr.
DTØ2	The integration time interval divided by 2, hr
DTØ24	The integration time interval divided by 24, hr
EYES	The amount of NaK in the stagnant NaK system, g
FS	The multiplier to convert the stagnant NaK hydrogen concentration to hydrogen partial pressure, micron-g/μg
FSB	The term FS_n/b_n appearing in equation (6)
NL	The number of boiler tantalum tube nodes that are not in equilibrium with the stagnant NaK
NZ	NL + 1
RWEXP	The term $1.0/WE_n$ appearing in equation (6)
TH	Same as CN for the NaK in the stagnant NaK system and the boiler tantalum tube nodes that are considered to be in equilibrium with the stagnant NaK, μg
THCH	+ (CH) (TH) (5)
THCN	+ (CN) (TH) (5)
THCS	+ (CS) (TH) (5)
TIME	The present time, from zero, of the calculation, hr
WPIN	The weight of hydrogen per length of hydrogen at the interface on the mercury side of the condenser, g/in.

Note: + See the note on page 10 in reference 1.

III. ANALYSIS

The analysis employed by DCHT is identical to that given in reference 1 with the exception of the boiler. Therefore, only the double containment boiler analysis will be given herein.

A portion of an axial half section of the boiler is given in Figure 2. For clarity, only one mercury tube is represented.

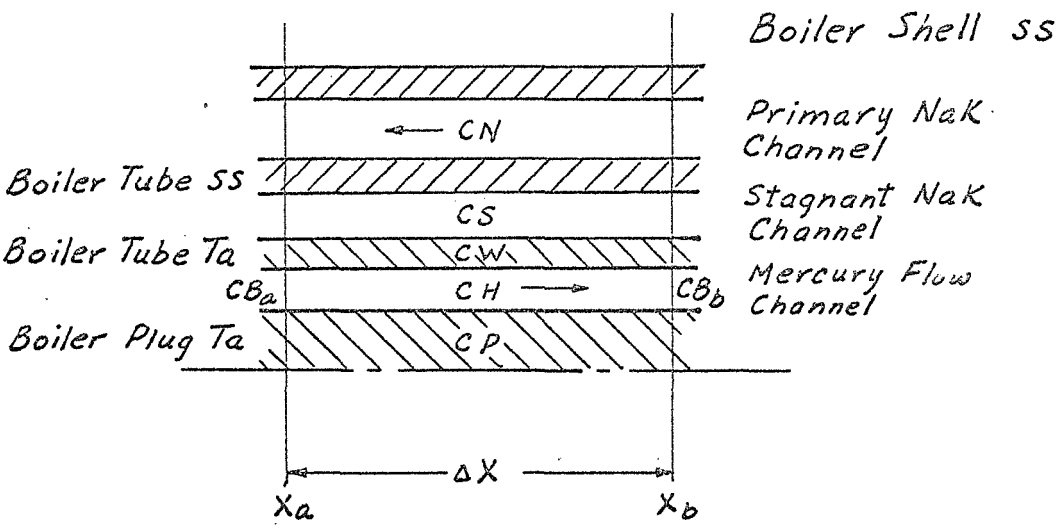

Figure 2 Axial-Half Section of the Boiler

Using a mass balance for the hydrogen in the primary and stagnant NaK and the tantalum tube and plug, the following equations are obtained.

$$\frac{\Delta CN}{\Delta\theta} = \frac{1}{I_N} \left[KN \cdot FS \cdot CS - (KL + KN)\, f \cdot CN\right] \tag{1}$$

$$\frac{\Delta CS}{\Delta\theta} = \frac{1}{I_S} \left[KN \cdot f \cdot CN + KS \cdot b \cdot CW^{WE} - (KN + KS)\, FS \cdot CS\right] \tag{2}$$

$$\frac{\Delta CW}{\Delta\theta} = \frac{1}{I_W} \left[KS \cdot FS \cdot CS + KW \cdot a \cdot CH - (KW + KS)\, b \cdot CW^{WE}\right] \tag{3}$$

$$\frac{\Delta CP}{\Delta\theta} = \frac{1}{I_P} \left[KP \cdot a \cdot CH - KP \cdot C \cdot CP^{PE}\right] \tag{4}$$

Making the same assumption for the primary NaK as in reference 1 (the hydrogen concentration is independent of position) and assuming that the hydrogen concentration in the stagnant NaK is constant throughout the system yields the following equation

$$\frac{\Delta CN}{\Delta\theta} = \frac{1}{I_{NT}} \left[CS \sum_{n=1}^{NHGB} KN_n\, FS_n - \left(JP + \sum_{n=1}^{NHGB} KN_n\, f_n\right) CN + SN\right] \tag{1a}$$

If it is assumed the NL tantalum tube nodes are at a low enough temperature that it is not in equilibrium with the stagnant NaK, the following adaptation of equation (2) describes their behavior.

$$\frac{\Delta CW_n}{\Delta\theta} = \frac{1}{I_{W_n}} \left[KS_n \cdot FS_n \cdot CS - KW_n \cdot a_n \cdot CH_n - (KW_n + KS_n)\, b_n \cdot CW_n^{WE_n}\right] \tag{2a}$$

$$n = 1 \rightarrow NL$$

If the remaining tantalum tube nodes are assumed to be in equilibrium with the stagnant NaK, introduction of a new parameter TH (total amount of hydrogen in the stagnant NaK system and the equilibrium tantalum tube nodes) will allow the following equations to be written to describe the movement and buildup of hydrogen in these nodes.

$$\frac{\Delta TH}{\Delta\theta} = CN \sum_{n=1}^{NHGB} KN_n \, f_n + \sum_{n=1}^{NL} KS_n \, b_n \, CW_n^{WE_n} + \sum_{n=NL+1}^{NHGB} KW_n \, a_n \, CH_n -$$

$$CS \sum_{n=1}^{NHGB} (KN_n + KS_n) \, FS_n \tag{5}$$

The total hydrogen term TH is allotted to the component nodes in accordance with the following equations

$$CW_n = \left[\frac{FS_n}{b_n} \, CS \right]^{1.0/WE_n} \tag{6}$$

$$n = NL + 1 \longrightarrow NHGB$$

$$TH = I_{ST} \cdot CS + \sum_{n=NL+1}^{NHGB} I_{W_n} \, CW_n \tag{7}$$

Equation (6) is a mathematical statement of the assumed equilibrium state existing between the tantalum tube and the stagnant NaK. Equation (7) represents a mass balance for the hydrogen.

The equations describing the behavior of the boiler mercury are identical to equations (4) and (6) in reference 1. It must be noted that where possible, the $b \cdot CW^{WE}$ term in the reference 1 equations have been replaced by its equivalent, $FS \cdot CS$ (i.e. when the tantalum and stagnant NaK are in equilibrium.

IV. PROGRAM DESCRIPTION

The makeup of the DCHT is almost identical to the SETH program described in reference 1. The only differences are 1) Renaming of the main program from CETHGO to DCHT and 2) Addition of the subroutine SOLNY. The remaining programs are either exactly as described in reference 1 or slightly modified thereof.

Subroutine SOLNY calculates the stagnant NaK and boiler tantalum tube hydrogen concentration given the total hydrogen in these nodes. SOLNY performs this calculation by using a trial and error, binary search technique to solve equations (6) and (7).

V. INPUT PREPARATION

The makeup of the input deck for DCHT is almost identical to that for SETH (reference 1). Several additional parameters have been added either to increase the code flexibility or to specify the parameters of the double containment boiler. These additions are made in the 2nd, 3rd and 4th card type and are described below. The remaining card type are exactly as described in reference 1.

2nd Card Type — Control & Material Parameters — I - FORMAT

Cols	FORTRAN Symbol	Definition
1 - 54	As described in reference 1	
55- 57	NXX(9)	If NXX(9) = 1, the input data are printed out. If NXX(9) = 0, they are not printed out.
58- 60	NXX(10)	The number of tantalum tube node(s) at the boiler mercury inlet that are not to be considered in equilibrium with the stagnant NaK. NXX(10) may be set equal to zero but must be less than the value of NHGB.

3rd Card Type — Miscellaneous Input — 6E12.4 FORMAT

Cols	FORTRAN Symbol	Definition
1st Card, 2nd Card, 3rd Card	As described in reference 1	
1 - 24		
25- 36	SLIC	Time zero hydrogen concentration in the stagnant NaK, μgH/g of NaK
37- 48	SLI	Stagnant NaK system, NaK inventory, lbs

4th Card

4th Card Type — Boiler Specifications — 6E12.4 FORMAT

Cols	FORTRAN Symbol	Definition
1st Card		
2nd Card		
3rd Card		As described in reference 1
1 - 60		
61- 72	SAT	Stagnant NaK annulus temperature, ^{o}F

4th Card

VI. SAMPLE PROBLEM

A sample problem was run on the IBM 1130 version of DCHT. The problem run, analyzed the SNAP-8 system, as defined by reference 2, with the double containment boiler as defined by reference 3.

A listing of the sample problem input deck and problem output is given in Appendix B. Note that the sample problem included surge tanks in the PNL and HRL. This was done to test out the portion of the code.

APPENDIX A

Main Program Listing

```
* * * * * * * * * * * * * * * * * * * *
* * * MAIN PROGRAM-DCHT-LISTING * * *
* * * * * * * * * * * * * * * * * * * *

C
C THIS IS THE MAIN DRIVER FOR THE DOUBLE CONTAINMENT BOILER VERSION OF
C THE HYDROGEN TRANSPORT CODE. FIRST
C
      COMMON CNSN,CNCN,CNCS,THCN,THCH(10),THCS,FSB(10),RWEXP(10),EYES
     1,EYEW(10),CWCS(10),CWCH(10),CWCW(10),WEXP(10),CBCB(20),CBCW(10)
     2,CBCP(10),CBSH(15),CHCB(20),CHCW(10),CHCP(10),CHSH(15),PEXP(10)
     3,CPCH(10),CPCP(10),CNCCC,CNCEL,NPLG,CBCNC(5),CHCNC(5),ELCB,ELEL
     4,A(20),B(10),C(10),WPIN,CNCCH(5)
C
C     SECOND COMMON INCLUDES CARD TYPES 1, 2, AND 3
      COMMON TITLE(18),NHGB,NHGBC,NHGC,NPL,NHRL,NXX(12),WH,SHP,ELTZ,
     1XSAC,CIT,CIP,PNI,HRLNI,SN,ERROR,DTP,TAD,DTCAL,ENDT,ENBT,ENCT,PNIC,
     2 HRLIC,RE1,RE2,CWZ(10),CPZ(10),SLI,SLIC
C     THIRD COMMON INCLUDES ALL OF THE REST OF THE INPUT DATA
      COMMON AXLB(10),TOSB(10),AOSRB(10),STB(10),BNT(10),TMTSS(10),
     1ASSR(10),SST(10),TMTTA(10),AWTAR(10),WTAT(10),SWD(10),
     2HGT(10),HGP(10),HGVQ(10),XSFA(10),HSINB(10),APT(10),PAR(10),
     3PT(10),PXSA(10),AREA(5),TOCW(5),WTEMP(5),HGTA(5),HGPA(5),HVQ(5),
     4VOL(5),HSINA(5),EMBC(5),AXLC(5),TOSC(5),AOSRC(5),STC(5),CNT(5),
     5TCT(5),ACTR(5),CTT(5),CHGT(5),CHGP(5),CHGVQ(5),CXSFA(5),ATPN(10)
      COMMON TOCSP(10),TOSP(10),TOPN(10),EMAP(10),ATHN(10),TOCSH(10),
     1TOSH(10),TOHN(10),EMAH(10),STNTP,STGTP,STGPP,STGLP,STNTH,STGTH,
     2 STGPH,STGLH,SAT(10)
C     FOURTH COMMON ARE THE VALUES NEEDED BETWEEN CALCY AND CALUY
      COMMON CAYN(10),CAYW(21),CAYP(10),F(15),FS(10),EYEP(10),SJP,SJH
C
C THIS COMMON CONTAINS THE TIME DEPENDENT VARIABLES. THE FIRST ONE IS THE
C PRESENT VALUE. THE SECOND IS THE PREVIOUS VALUE
C
      COMMON CN(2),CW(2,10),CP(2,10),CNC(2),EL(2),TH(2),CS(2)
     1 ,CB(21),CH(20),NL,NZ,TIME,DTO2,DTO24
C
C THIS COMMON CONTAINS THE SLOPE OF THE TIME DEPENDENT VALUES
      COMMON DCN(4),DCW(4,10),DCP(4,10),DCNC(4),DEL(4),DTH(4)
 5000 CALL SETH
      CALL CALCY
      CALL CALUY
      CALL INTGY
      GO TO 5000
      END
```

END

APPENDIX B

Sample Inputs and Outputs

```
* * * * * * * * * * * * * * * * * *
* * * SAMPLE INPUT FOR DCHT * * *
* * * * * * * * * * * * * * * * * *
```

```
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-   T
     9     3     2     4     3  1  1  1  1  1  1  1  1  1  1                CMI
11500.     35.95      0.        .02956     680.       15.5          MI1
256.5      64.5       5392.     .99999     2.0        1036.         MI2
1.0        10.0       7.0       73.0       0.         0.            MI3
0.9        0.05       0.0       20.0                                MI4
6.0        0.25       2.7       1135.      1135.      0.035         BS1A
.483       500.       .04       .355       500.       0.            BS1B
0.         500.       332.      0.         .1         0.            BS1C
500.       .0625      .0625     .0491      0.0        500.          BS1D
12.0       0.25       2.7       1146.      1146.      0.035         BS2A
.483       1026.      .04       .355       860.       0.            BS2B
0.0        800.       332.      0.         .08117     0.            BS2C
800.       .163       .163      .2713      0.0        965.          BS2D
20.4       0.25       2.7       1165.      1165.      0.035         BS3A
.483       1143.      .04       .355       1111.      0.            BS3B
0.0        1100.      329.      .047       .08117     0.            BS3C
1100.      .163       .163      .2713      0.0        1122.         BS3D
20.4       0.25       2.7       1178.      1178.      0.035         BS4A
.483       1148.      .04       .355       1113.      0.            BS4B
0.0        1100.      305.      .141       .08117     0.            BS4C
1100.      .163       .163      .2713      0.0        1128.         BS4D
75.        0.25       2.7       1220.      1220.      0.035         BS5A
.483       1172.      .04       .355       1115.      .063          BS5B
0.0        1089.      297.      .428       .3525      0.            BS5C
0.         0.         0.        0.         0.         1140.         BS5D
75.        0.25       2.7       1272.      1272.      0.035         BS6A
.483       1212.      .04       .355       1189.      .063          BS6B
0.0        1087.      294.      .806       .3525      0.            BS6C
0.         0.         0.        0.         0.         1219.         BS6D
80.28      0.25       2.7       1297.1     1297.1     0.035         BS7A
.483       1257.      .04       .355       1212.      .063          BS7B
0.0        1085.      290.      .972       .3525      0.            BS7C
0.         0.         0.        0.         0.         1235.         BS7D
65.64      0.25       2.7       1327.      1327.      0.035         BS8A
.483       1287.      .04       .355       1239.      .063          BS8B
0.0        1176.      277.      1.0        .3525      0.            BS8C
0.         0.         0.        0.         0.         1259.         BS8D
95.28      0.25       2.7       1330.      1330.      0.035         BS9A
.483       1320.      .04       .355       1307.      .063          BS9B
0.0        1285.      270.      1.0        .3525      0.            BS9C
0.         0.         0.        0.         0.         1312.         BS9D
```

521.3	.120	1285.	1285.	265.	1.0	BCS1A
323.	0.	2.0				BCS1B
188.	.25	982.	982.	265.	.95	BCS2A
188.	53.8	1.0				BCS2B
132.	.05	680.	680.	265.	.95	BCS3A
198.	0.	1.0				BCS3B
20.2	.063	2.88	670.	675.	.03	CS1A
.1845	680.	680.	15.5	.75	.1069	CS1B
20.2	.063	2.5	600.	605.	.03	CS2A
.1096	680.	680.	15.5	.3	.03773	CS2B
1118.9	.049	1307.	1307.5	1.0		PNL1
1290.	.049	1134.5	1135.	1.0		PNL2
609.	.125	1134.5	1135.	1.0		PNL3
1135.	.049	1134.5	1135.	1.0		PNL4
779.	.049	660.	660.	1.0		HRL1
14774.	.02	574.	574.	1.0		HRL2
779.	.049	488.	488.	1.0		HRL3
1310.	1000.	30.	1000.			PNLST
700.	600.	30.	1000.			HRLST

END

00065 CARDS

TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

HG. FLOW RATE LB/HR	H. SOURCE HG. PMA MICRO GM/HR	INITIAL LENGTH OF H. INTERFACE IN COND. IN.	HG. XSECT. FLOW AREA AT COND. INTERFACE SQ. IN.	COND. INTER-FACE TEMP. DEG. F.	COND. INTER FACE PRESS PSIA
11500.0	0.35950E 02	0.00000E 00	0.29560E-01	680.0	15.50

PRIMARY NAK INVENTORY LB.	HR LOOP NAK INVENTORY LB.	H. SOURCE REACTOR MICRO GM/HR	CRITERION FOR EQUILIBRIUM	PRINTING TIME HR.	DENSITY OF TANTALUM LB/CU FT.
0.256500E 03	0.645000E 02	0.539200E 04	0.999E 00	0.2000E 01	1036.00

INTEGRATION TIME HR.	MAX. INTEGRATION TIME HR.	NO. OF BOILER TUBES	NO. OF COND. TUBES	PRIM. NAK H. CONC. AT ZERO MICRO GM/GM.	HRL NAK H. CONC. AT ZERO MICRO GM/GM.
0.1000E 01	0.1000E 02	7.	73.	0.0000E 00	0.0000E 00

FRACTION H. THRU COND. INTERFACE	FRACTION H. RECYCLED TO BOILER	STAGNANT NAK ANNULUS TIME-0 CONC MICROGMS/GM	INVENTORY LBS.
0.900000	0.050000	0.00000E 00	20.00

BOILER SPECIFICATIONS - THERE ARE 9 VALUES OF EACH PARAMETER

AXIAL LENGTH OF EACH NODE, IN.

6.00	12.00	20.40	20.40	75.00
75.00	80.28	65.64	95.28	

THICKNESS OF OUTER SHELL, IN.

0.2500	0.2500	0.2500	0.2500	0.2500
0.2500	0.2500	0.2500	0.2500	

AVERAGE OUTER SHELL RADIUS, IN.

2.7000	2.7000	2.7000	2.7000	2.7000
2.7000	2.7000	2.7000	2.7000	

SHELL TEMP., DEG. F.

1135.0	1146.0	1165.0	1178.0	1220.0
1272.0	1297.1	1327.0	1330.0	

BOILER SPECIFICATIONS CONTINUED

BOILER NAK TEMP., DEG. F.

1135.0	1146.0	1165.0	1178.0	1220.0
1272.0	1297.1	1327.0	1330.0	

THICKNESS OF HG. TUBE STAINLESS STEEL, IN.

0.0350	0.0350	0.0350	0.0350	0.0350
0.0350	0.0350	0.0350	0.0350	

AVERAGE RADIUS OF STAINLESS STEEL TUBE, IN.

0.4830	0.4830	0.4830	0.4830	0.4830
0.4830	0.4830	0.4830	0.4830	

TEMP. OF STAINLESS STEEL TUBE, DEG. F.

500.0	1026.0	1143.0	1148.0	1172.0
1212.0	1257.0	1287.0	1320.0	

THICKNESS OF HG. TUBE TANTALUM, IN.

0.0400	0.0400	0.0400	0.0400	0.0400
0.0400	0.0400	0.0400	0.0400	

AVERAGE WALL RADIUS OF TANTALUM TUBE, IN.

0.3550	0.3550	0.3550	0.3550	0.3550
0.3550	0.3550	0.3550	0.3550	

WALL TEMP. OF TANTALUM TUBE, DEG. F.

500.0	860.0	1111.0	1113.0	1115.0
1189.0	1212.0	1239.0	1307.0	

SWIRL WIRE DIA., IN.

0.0000	0.0000	0.0000	0.0000	0.0630
0.0630	0.0630	0.0630	0.0630	

HYDROGEN CONC. AT TIME ZERO, MICRO GM H2/GM TA.

0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

MERCURY TEMP., DEG. F.

500.0	800.0	1100.0	1100.0	1089.0
1087.0	1085.0	1176.0	1285.0	

BOILER SPECIFICATIONS CONTINUED

MERCURY PRESSURE, PSIA

332.0	332.0	329.0	305.0	297.0
294.0	290.0	277.0	270.0	

MERCURY VAPOR QUALITY, WEIGHT FRACTION

0.0000	0.0000	0.0470	0.1410	0.4280
0.8060	0.9720	1.0000	1.0000	

CROSS-SECTIONAL FLOW AREA, SQ. IN.

0.10000E 00	0.81170E-01	0.81170E-01	0.81170E-01	0.35250E 00
0.35250E 00	0.35250E 00	0.35250E 00	0.35250E 00	

HYDROGEN SOURCE IN HG., MICRO GM H2/HR

0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

AVERAGE PLUG TEMP., DEG. F.

500.0	800.0	1100.0	1100.0	0.0
0.0	0.0	0.0	0.0	

PLUG AVERAGE RADIUS, IN.

0.0625	0.1630	0.1630	0.1630	0.0000
0.0000	0.0000	0.0000	0.0000	

PLUG THICKNESS, IN.

0.0625	0.1630	0.1630	0.1630	0.0000
0.0000	0.0000	0.0000	0.0000	

PLUG CROSS-SECTIONAL AREA, SQ. IN.

0.49100E-01	0.27130E 00	0.27130E 00	0.27130E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

HYDROGEN CONC. AT TIME ZERO, MICRO GM H2/GM TA

0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

STAGNANT NAK TEMPERATURE(DEG.F)

500.0	965.0	1122.0	1128.0	1140.0
1219.0	1235.0	1259.0	1312.0	

BOILER TO CONDENSER SPECIFICATIONS - THERE ARE 3 VALUES OF EACH PARAMETER

HYDROGEN TRANSPORT AREA, SQ. IN.		
0.52130E 03	0.18800E 03	0.13200E 03
THICKNESS OF CONTAINMENT WALL, IN.		
0.1200	0.2500	0.0500
WALL TEMP., DEG. F.		
1285.0	982.0	680.0
HG. TEMP., DEG. F.		
1285.0	982.0	680.0
HG. PRESS., PSIA		
265.0	265.0	265.0
HG. VAPOR QUALITY, WEIGHT FRACTION		
1.0000	0.9500	0.9500
HG. FLOW VOLUME, CU. IN.		
0.32300E 03	0.18800E 03	0.19800E 03
HYDROGEN SOURCE TERM. IN NODE, MICRO GM H2/HR.		
0.00000E 00	0.53800E 02	0.00000E 00
MATERIAL INDEX NUMBER		
2.0	1.0	1.0

CONDENSER SPECIFICATIONS, THERE ARE 2 VALUES OF EACH PARAMETER

AXIAL LENGTH OF EACH NODE, IN.

20.20	20.20

THICKNESS OF OUTER SHELL, IN.

0.0630	0.0630

AVERAGE OUTER SHELL RADIUS, IN.

2.8800	2.5000

SHELL TEMP., DEG. F.

670.0	600.0

CONDENSER NAK TEMP., DEG. F.

675.0	605.0

THICKNESS OF CONDENSER TUBE, IN.

0.0300	0.0300

AVERAGE CONDENSER TUBE RADIUS, IN.

0.1845	0.1096

CONDENSER TUBE TEMP., DEG. F.

680.0	680.0

CONDENSER HG. TEMP., DEG. F.

680.0	680.0

CONDENSER HG. PRESS., PSIA

15.5	15.5

CONDENSER HG. VAPOR QUALITY, WEIGHT FRACTION

0.7500	0.3000

CONDENSER HG. FLOW AREA, SQ. IN.

0.10690E 00	0.37730E-01

PRIMARY NAK SIDE LOSS TERMS - THERE ARE 4 VALUES OF EACH PARAMETER

AREA OF HYDROGEN TRANSPORT PRIMARY NAK, SQ. IN.			
0.11189E 04	0.12900E 04	0.60900E 03	0.11350E 04
THICKNESS OF CONTAINMENT SHELL, IN.			
0.0490	0.0490	0.1250	0.0490
TEMP. OF SHELL, DEG. F.			
1307.0	1134.5	1134.5	1134.5
TEMP. OF PRIMARY NAK, DEG. F.			
1307.5	1135.0	1135.0	1135.0
MATERIAL INDEX NUMBER			
1.0	1.0	1.0	1.0

HRL NAK SIDE LOSS TERMS - THERE ARE 3 VALUES OF EACH PARAMETER

AREA OF HYDROGEN TRANSPORT HRL NAK, SQ. IN.		
0.77900E 03	0.14774E 05	0.77900E 03
THICKNESS OF CONTAINMENT SHELL, IN.		
0.0490	0.0200	0.0490
TEMP. OF CONTAINMENT SHELL, DEG. F.		
660.0	574.0	488.0
TEMP. OF HRL NAK, DEG. F.		
660.0	574.0	488.0
MATERIAL INDEX NUMBER		
1.0	1.0	1.0

SURGE TANK SPECIFICATIONS

PNL SURGE TANK NAK TEMP. DEG. F.	PNL SURGE TANK GAS TEMP. DEG. F.	PNL SURGE TANK GAS PRESS. PSIA	PNL SURGE TANK GAS LEAKAGE CC/HR.
1310.0	1000.0	30.00	0.10000E 04

HRL SURGE TANK NAK TEMP. DEG. F.	HRL SURGE TANK GAS TEMP. DEG. F.	HRL SURGE TANK GAS PRESS. PSIA	HRL SURGE TANK GAS LEAKAGE CC/HR.
700.0	600.0	30.00	0.10000E 04

RESULTS OF INTERMEDIATE COEFFICIENTS

CAYN VALUES

0.16424E-02	0.18617E 01	0.73633E 01	0.76129E 01	0.32754E 02
0.42141E 02	0.59058E 02	0.57346E 02	0.99900E 02	

F VALUES

0.91334E 01	0.87326E 01	0.80929E 01	0.76902E 01	0.65565E 01
0.54396E 01	0.49905E 01	0.45178E 01	0.44737E 01	0.13000E 03
0.23814E 03				

B VALUES

0.31611E-02	0.59463E-01	0.35794E 00	0.36279E 00	0.36771E 00
0.59955E 00	0.69540E 00	0.82581E 00	0.12597E 01	

WEXP VALUES

0.24166E 01	0.25948E 01	0.25917E 01	0.25912E 01	0.25908E 01
0.25694E 01	0.25609E 01	0.25498E 01	0.25165E 01	

EYEW VALUES

0.10189E 04	0.20379E 04	0.34645E 04	0.34645E 04	0.13182E 05
0.13182E 05	0.14110E 05	0.11537E 05	0.16747E 05	

CAYW VALUES(IDENTICAL TO CAYS)

0.75949E-05	0.26938E 03	0.12520E 05	0.12567E 05	0.46379E 05
0.52930E 05	0.58891E 05	0.50321E 05	0.81134E 05	0.25090E 02
0.13504E 00	0.20141E-01	0.43472E 00	0.25824E 00	0.24178E 01

A VALUES

0.22862E 06	0.29086E 06	0.36022E 05	0.11131E 05	0.35710E 04
0.18771E 04	0.15353E 04	0.14254E 04	0.13894E 04	0.13637E 04
0.14354E 04	0.14354E 04	0.10635E 03	0.26588E 03	

RESULTS OF INTERMEDIATE COEFFICIENTS CONTINUED

CAYP VALUES

0.42788E-06	0.18229E 01	0.69087E 03	0.69087E 03

C VALUES

0.31611E-02	0.37552E-01	0.33229E 00	0.33229E 00

PEXP VALUES

0.24166E 01	0.25800E 01	0.25940E 01	0.25940E 01

EYEP VALUES

0.56077E 03	0.61970E 04	0.10534E 05	0.10534E 05

FS VALUES

0.69673E 03	0.19957E 02	0.96386E 01	0.94011E 01	0.89483E 01
0.65808E 01	0.62054E 01	0.56936E 01	0.47470E 01	

VALUE OF SJP,SJH,WPIN AND EYES

0.22565E 04	0.53378E 03	0.13517E 04	0.90718E 04

THE CALCULATED COMBINED COEFFICIENTS

VALUE OF CNSN,CNCN,CNCS AND THCN

0.46344E-01	-0.19395E-01	0.16489E-01	0.15791E 04

VALUE OF THCS,ELEL,ELCB,CNCCC AND CNCEL

-0.20465E 07	-0.17887E-02	0.38589E 03	-0.18244E-01	0.82643E-04

VALUES OF FS/B

0.33561E 03	0.26928E 02	0.25912E 02	0.24335E 02	0.10976E 02
0.89234E 01	0.68945E 01	0.37682E 01		

VALUES OF 1./WEXP

0.38538E 00	0.38584E 00	0.38590E 00	0.38597E 00	0.38918E 00
0.39047E 00	0.39217E 00	0.39736E 00		

VALUES OF CWCS

0.51930E-05

VALUES OF CWCH

0.17040E-02

VALUES OF CWCW

0.23560E-10

VALUES OF CBCB

0.99999E 00	0.27060E-06	0.00000E 00	0.51505E-12	0.16253E-13
0.53437E-08	0.29642E-07	0.10660E-05	0.41137E-09	0.99346E 00
0.99996E 00	0.99999E 00	0.99999E 00	0.99998E 00	

VALUES OF CHCB

0.99999E 00	0.66126E-01	0.10960E-01	0.35342E-01	0.31495E-01
0.52500E-01	0.57689E-01	0.72719E-01	0.46271E-01	0.99672E 00
0.99998E 00	0.99999E 00	0.99999E 00	0.99999E 00	

VALUES OF CPCP

-0.24120E-11	-0.11046E-04	-0.21791E-01	-0.21791E-01

THE CALCULATED COMBINED COEFFICIENTS(CONTINUED)

VALUES OF CBSH

0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.10313E-04	0.00000E 00			

VALUES OF CHSH

0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
0.51568E-05	0.00000E 00			

VALUES OF CBCW OR CBCS

0.10144E-08	0.20306E-06	0.94169E-05	0.30893E-04	0.10297E-03
0.31940E-03	0.45292E-03	0.57932E-03	0.90666E-03	

VALUES OF CHCW OR CHCS

0.50722E-09	0.18963E-06	0.93137E-05	0.29801E-04	0.99729E-04
0.30263E-03	0.42679E-03	0.53719E-03	0.86471E-03	

VALUES OF CBCP

0.25930E-15	0.86783E-09	0.48237E-06	0.15554E-05

VALUES OF CHCP

0.12965E-15	0.81044E-09	0.47708E-06	0.15004E-05

CNCCH VALUES

0.15803E-02	0.23469E-02

CHCNC VALUES

0.54172E-05	0.58948E-05

CBCNC VALUES

0.10834E-04	0.11789E-04

VALUES OF THCH/THCW

0.24008E-07	0.16018E 02	0.44817E 04	0.45596E 04	0.17054E 05
0.31734E 05	0.40953E 05	0.41556E 05	0.10221E 06	

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 0.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74075E-05	0.74075E-05	0.20044E-11	0.00000E 00	0.00000E 00
	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
	0.00000E 00	0.10313E-04	0.10313E-04	0.10313E-04	0.10313E-04
HG AT THE NODE POINT	0.74075E-05	0.48982E-06	0.21969E-13	0.00000E 00	0.00000E 00
	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
	0.51568E-05	0.10313E-04	0.10313E-04	0.10313E-04	
TA IN THE BOILER TUBE WALL	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	
TA IN THE BOILER PLUG	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

THE NAK SIDE PRIMARY= 0.00000E 00 STAGNANT= 0.00000E 00 HEAT REJ.= 0.00000E 00

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.00000E 00 INCHES 0.00000E 00 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - - -

HG AT THE NODE POINT	0.16935E 01	0.14247E 00	0.79141E-09	0.00000E 00	0.00000E 00
	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
	0.74026E-02	0.14805E-01	0.10968E-02	0.27421E-02	
TA IN THE BOILER TUBE WALL	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00
	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	
TA IN THE BOILER PLUG	0.00000E 00	0.00000E 00	0.00000E 00	0.00000E 00	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 2.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74075E-05	0.74075E-05	0.20060E-11	0.71844E-13	0.23569E-12
	0.78560E-12	0.24368E-11	0.34554E-11	0.44198E-11	0.69172E-11
	0.68720E-11	0.10313E-04	0.10313E-04	0.10313E-04	0.10313E-04
HG AT THE NODE POINT	0.74075E-05	0.48982E-06	0.93044E-13	0.22990E-12	0.76828E-12
	0.23501E-11	0.33967E-11	0.43497E-11	0.68016E-11	0.68946E-11
	0.51568E-05	0.10313E-04	0.10313E-04	0.10313E-04	
TA IN THE BOILER TUBE WALL	0.25245E-07	0.69983E-02	0.26283E-02	0.25870E-02	0.25224E-02
	0.17604E-02	0.15899E-02	0.13972E-02	0.10074E-02	
TA IN THE BOILER PLUG	0.25844E-08	0.83823E-04	0.19311E-09	0.89278E-10	

THE NAK SIDE PRIMARY= 0.90916E-01 STAGNANT= 0.76292E-08 HEAT REJ.= 0.13946E-05

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.15876E-01 INCHES 0.21461E-04 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - -

HG AT THE NODE POINT	0.16935E 01	0.14247E 00	0.33517E-08	0.25592E-08	0.27435E-08
	0.44114E-08	0.52151E-08	0.62004E-08	0.94505E-08	0.94022E-08
	0.74026E-02	0.14805E-01	0.10968E-02	0.27421E-02	
TA IN THE BOILER TUBE WALL	0.13770E-20	0.15219E-06	0.73504E-07	0.71692E-07	0.68240E-07
	0.50185E-07	0.47322E-07	0.43419E-07	0.36201E-07	
TA IN THE BOILER PLUG	0.55842E-23	0.11392E-11	0.21004E-25	0.28386E-26	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 4.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74075E-05	0.74075E-05	0.20574E-11	0.24552E-11	0.80546E-11
	0.26847E-10	0.83275E-10	0.11808E-09	0.15104E-09	0.23638E-09
	0.23484E-09	0.10313E-04	0.10313E-04	0.10313E-04	0.10313E-04
HG AT THE NODE POINT	0.74075E-05	0.48983E-06	0.24508E-11	0.78567E-11	0.26255E-10
	0.80313E-10	0.11607E-09	0.14864E-09	0.23244E-09	0.23561E-09
	0.51570E-05	0.10313E-04	0.10313E-04	0.10313E-04	
TA IN THE BOILER TUBE WALL	0.50492E-07	0.27287E-01	0.10264E-01	0.10105E-01	0.98557E-02
	0.69571E-02	0.63118E-02	0.55802E-02	0.40979E-02	
TA IN THE BOILER PLUG	0.51689E-08	0.16764E-03	0.42162E-08	0.40069E-08	

THE NAK SIDE PRIMARY= 0.17837E 00 STAGNANT= 0.26072E-06 HEAT REJ.= 0.52821E-05

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.27705E-01 INCHES 0.37450E-04 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - -

HG AT THE NODE POINT	0.16935E 01	0.14247E 00	0.88286E-07	0.87458E-07	0.93758E-07
	0.15075E-06	0.17822E-06	0.21189E-06	0.32296E-06	0.32131E-06
	0.74029E-02	0.14805E-01	0.10968E-02	0.27422E-02	
TA IN THE BOILER TUBE WALL	0.73525E-20	0.51979E-05	0.25104E-05	0.24486E-05	0.23306E-05
	0.17140E-05	0.16162E-05	0.14829E-05	0.12364E-05	
TA IN THE BOILER PLUG	0.29815E-22	0.68125E-11	0.62524E-22	0.54788E-22	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 6.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74076E-05	0.74076E-05	0.24129E-11	0.18939E-10	0.62133E-10
	0.20709E-09	0.64238E-09	0.91092E-09	0.11651E-08	0.18235E-08
	0.18115E-08	0.10315E-04	0.10315E-04	0.10315E-04	0.10315E-04
HG AT THE NODE POINT	0.74076E-05	0.48983E-06	0.18758E-10	0.60606E-10	0.20253E-09
	0.61953E-09	0.89543E-09	0.11466E-08	0.17930E-08	0.18175E-08
	0.51586E-05	0.10315E-04	0.10315E-04	0.10315E-04	
TA IN THE BOILER TUBE WALL	0.75747E-07	0.60029E-01	0.22602E-01	0.22255E-01	0.21708E-01
	0.15424E-01	0.14031E-01	0.12447E-01	0.92390E-02	
TA IN THE BOILER PLUG	0.77534E-08	0.25146E-03	0.44718E-07	0.44388E-07	

THE NAK SIDE PRIMARY= 0.26250E 00 STAGNANT= 0.20112E-05 HEAT REJ.= 0.10577E-04

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.35553E-01 INCHES 0.48058E-04 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - -

HG AT THE NODE POINT	0.16935E 01	0.14247E 00	0.67572E-06	0.67465E-06	0.72324E-06
	0.11629E-05	0.13748E-05	0.16345E-05	0.24913E-05	0.24786E-05
	0.74052E-02	0.14807E-01	0.10970E-02	0.27426E-02	
TA IN THE BOILER TUBE WALL	0.19593E-19	0.40208E-04	0.19419E-04	0.18940E-04	0.18028E-04
	0.13258E-04	0.12502E-04	0.11471E-04	0.95642E-05	
TA IN THE BOILER PLUG	0.79429E-22	0.19392E-10	0.28602E-19	0.28058E-19	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 8.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74079E-05	0.74079E-05	0.37091E-11	0.79046E-10	0.25932E-09
	0.86435E-09	0.26810E-08	0.38018E-08	0.48629E-08	0.76106E-08
	0.75608E-08	0.10321E-04	0.10321E-04	0.10321E-04	0.10321E-04
HG AT THE NODE POINT	0.74079E-05	0.48985E-06	0.78220E-10	0.25294E-09	0.84529E-09
	0.25857E-08	0.37372E-08	0.47857E-08	0.74834E-08	0.75857E-08
	0.51644E-05	0.10321E-04	0.10321E-04	0.10321E-04	
TA IN THE BOILER TUBE WALL	0.10104E-06	0.10413E 00	0.39234E-01	0.38635E-01	0.37688E-01
	0.26902E-01	0.24517E-01	0.21803E-01	0.16303E-01	
TA IN THE BOILER PLUG	0.10338E-07	0.33529E-03	0.24852E-06	0.24800E-06	

THE NAK SIDE PRIMARY= 0.34342E 00 STAGNANT= 0.83940E-05 HEAT REJ.= 0.17182E-04

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.43375E-01 INCHES 0.58632E-04 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - -

HG AT THE NODE POINT	0.16936E 01	0.14248E 00	0.28177E-05	0.28157E-05	0.30185E-05
	0.48536E-05	0.57379E-05	0.68219E-05	0.10397E-04	0.10344E-04
	0.74134E-02	0.14815E-01	0.10976E-02	0.27442E-02	
TA IN THE BOILER TUBE WALL	0.39310E-19	0.16790E-03	0.81091E-04	0.79092E-04	0.75283E-04
	0.55365E-04	0.52206E-04	0.47901E-04	0.39937E-04	
TA IN THE BOILER PLUG	0.15918E-21	0.40737E-10	0.24472E-17	0.24339E-17	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

OUTPUT FOR PROBLEM TITLED
TEST CASE FOR DCHT(DOUBLE CONTAINMENT H TRANSPORT) AGC NUC.DIV. -NEMO-

TIME= 10.0 HOURS - - - - HYDROGEN CONCENTRATION (MICROGMS/GM OF MATERIAL) IN - - - -

HG AT THE NODE BOUNDARIES	0.74086E-05	0.74086E-05	0.69946E-11	0.23139E-09	0.75913E-09
	0.25302E-08	0.78485E-08	0.11129E-07	0.14235E-07	0.22279E-07
	0.22133E-07	0.10335E-04	0.10335E-04	0.10335E-04	0.10336E-04
HG AT THE NODE POINT	0.74086E-05	0.48990E-06	0.22893E-09	0.74047E-09	0.24745E-08
	0.75693E-08	0.10940E-07	0.14009E-07	0.21907E-07	0.22206E-07
	0.51789E-05	0.10335E-04	0.10335E-04	0.10335E-04	
TA IN THE BOILER TUBE WALL	0.12644E-06	0.15755E 00	0.59391E-01	0.58488E-01	0.57059E-01
	0.40870E-01	0.37298E-01	0.33230E-01	0.24987E-01	
TA IN THE BOILER PLUG	0.12922E-07	0.41912E-03	0.92638E-06	0.92547E-06	

THE NAK SIDE PRIMARY= 0.42127E 00 STAGNANT= 0.24572E-04 HEAT REJ.= 0.25077E-04

AMOUNT OF HYDROGEN AT THE CONDENSER INTERFACE 0.51177E-01 INCHES 0.69178E-04 GRAMS

- - - - - - - - -HYDROGEN PARTIAL PRESSURE(MICRONS) IN- - - - - - - -

HG AT THE NODE POINT	0.16938E 01	0.14249E 00	0.82470E-05	0.82427E-05	0.88365E-05
	0.14208E-04	0.16797E-04	0.19970E-04	0.30438E-04	0.30283E-04
	0.74343E-02	0.14836E-01	0.10992E-02	0.27481E-02	
TA IN THE BOILER TUBE WALL	0.67595E-19	0.49170E-03	0.23747E-03	0.23162E-03	0.22046E-03
	0.16213E-03	0.15288E-03	0.14027E-03	0.11695E-03	
TA IN THE BOILER PLUG	0.27297E-21	0.72451E-10	0.74300E-16	0.74110E-16	

NOTE-THE VALUES ARE IN SEQUENCE FROM THE BOILER HG INLET TO THE CONDENSER INTERFACE

APPENDIX C

References

(1) Yee, D., "SETH-SNAP-8 Hydrogen Transport Computer Program", TM 4923:67-501, Aerojet-General Corporation, 5 December 1967.

(2) Miller, A. R., "Hydrogen Transport in SNAP-8", AN-SNAP-66-314, Aerojet-General Corporation, 13 September 1966.

(3) Sellers, A. J., "Bare Refractory Double Containment Boiler Design Analysis", TM 4934:67-477, Aerojet-General Corporation, 30 June 1967.